3-D Video Analysis Using WinAnalyze® Software

3-D video analysis offers the only objective possibility to document moving works in space. After the video recording of the moving work using two video cameras from two positions, WinAnalyze® Software calculates the change in defined points on the moving object in space over time.
The following document should allow laypersons to conduct their own estimation of the applicability of this form of documentation for a given work. If no outside firm is contracted, then application by oneself is also possible with training, basic resources, and manageable costs.

Suitability of 3-D Video Analysis for Documenting the Movements of Artworks

3-D analysis is suitable for

– Works whose movements run quicker than the eye can register, whereby slow movements can also be analyzed.

– Works whose movements strongly tend towards three-dimensionality. (In simpler cases, a two-dimensional analysis can be conducted with just one camera.)

– Works whose movement apparatus constantly remains visible from two angles.

Disadvantages of 3-D Video Analysis for the Documentation of the Movements of Artworks

- The resolution of video cameras currently available is too low for the software to be able to work accurately during the analysis. High-speed cameras, such as those used in industry and in biometrics, deliver finer images and thus more accurate results.
- Overlappings, even minimal ones, hinder the accurate filming of the moving object. In such cases, the analyzed points have to be moved by hand with the mouse during tracking which leads to inaccuracies.
- The movement is observed completely independently of the physical characteristics of the work.

Effort and Costs of Producing One's Own Analysis

- Only the calibrating model and both video cameras are needed for the production of video sequences.
- For autodidactic training in the software to a satisfactory degree, one should reckon with investing a week's effort. After training, all further analyses are easier to estimate and also easier to realize.

– In summer 2006 the rent for 5 working days was circa 700 euros.[1] It has been noted that other, equivalent programs are on the market which, however, were not taken into consideration in this project.

Producing the Video Sequences

Two video sequences of the same movement from two different angles are required to conduct a 3-D video analysis:

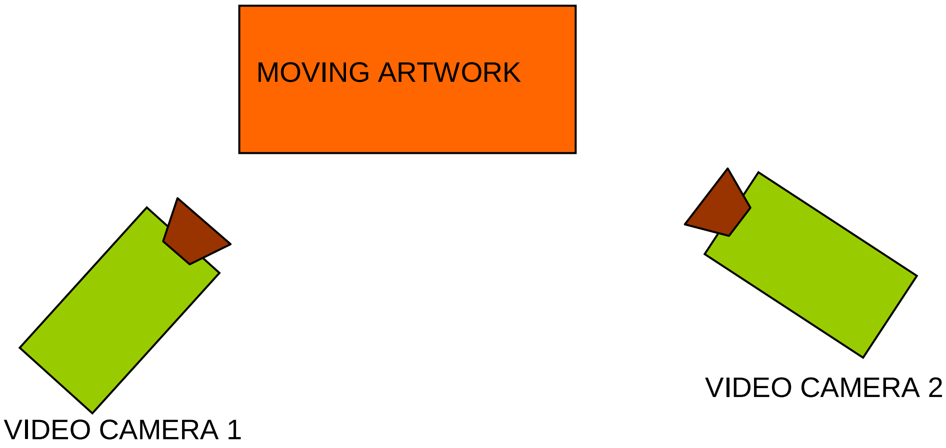

Fig. 1: Situation of a 3-D video recording

Cameras

Two identically constructed cameras with the same optic are a prerequisite for recordings. The higher the resolution of the video sequences, the greater the chances of successful analysis. High-speed cameras are employed for very fast movements in technical and biometric applications which are on the fringes of what the human eye can register. At present, these cameras as well as the corresponding picture processing systems are still very specialized and thus expensive. For this reason, contracting a specialized firm is advised with such an application. The firm VIDEAL offers such a service, however it only rents out WinAnalyze® software.

The video sequences have to be presented in AVI format for processing with the WinAnalyze® software.

In the examples below two cameras of the following type were used:

Digital Camera Recorder Sony DCR-TRV50E

Wide Conversion Lens VCL-HG0737X

Electret Condenser Zoom-Microphone ECM-HS1 is automatically synchronized with the camcorders' zoom.

[1] Information at www.VIDEAL.ch.

Positioning the Cameras

The position of both video cameras is crucial: Later during the evaluation with help from the software, concise points are marked on the work which define the movement. These points have to be visible at all times during the recordings. To that end, the positions of both video cameras must be selected. The second important factor consists in later having to calibrate both views. For that purpose, a spherical or cuboid model is defined in both views which serves to calibrate both recordings. (see the section "Calibration Model")

Synchronizing the Cameras

The video sequences have to be synchronized, so that both video sequences record exactly the same sequence of movement at the same time. This is achieved either with synchronizable video cameras via an acoustic or optical signal—as brief as possible—with whose help both video sequences can be synchronized later in the cutting room. Such signals can be a flash of light or equally a short bang. The shorter and more exact the signal, the more exactly can the video sequences can be synchronized in the cutting room. A handclap was used as a synchronizing aid in the three examples in this document. Later, both video sequences were synchronically cut accordingly to begin with the handclap.

Calibration Model

A calibration model is required before every recording with whose help both recordings can be brought into a unitary spatial system in the later analysis. This model can take the form of a sphere or a cuboid and requires a certain minimum number of visible points. The minimum for the cuboid model is 12 points which can most easily be measured by hand. The model can be defined on the basis of the components of the work, so long as it is suitable for that. Otherwise, a custom-made slat model can also be suitable, installed around the work or directly next to it and which is visible in as many points in the recordings as possible, at least at the beginning. Later, this model is reconstructed in the software and provided with the real masses. The calibration methods handled in the examples below prove to be lacking, because not all points on the model were to be seen simultaneously.

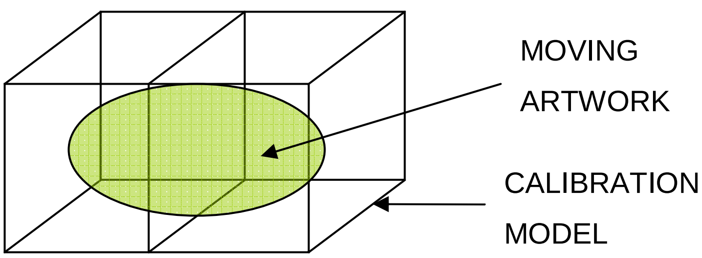

Fig. 2: Example of twelve points of a simple calibration model

Encoding the Video Sequences

Video sequences in AVI format can reveal multiple encodings. WinAnalyze® cannot support all encodings, which is why the video sequences have to be converted under certain circumstances. According to a statement by the firm VIDEAL, an AVI sequence in the "Intel Video 4.5" encoding is optimal for use in WinAnalyze®. Programs, such as VideoMach® for example, exist for conversion.

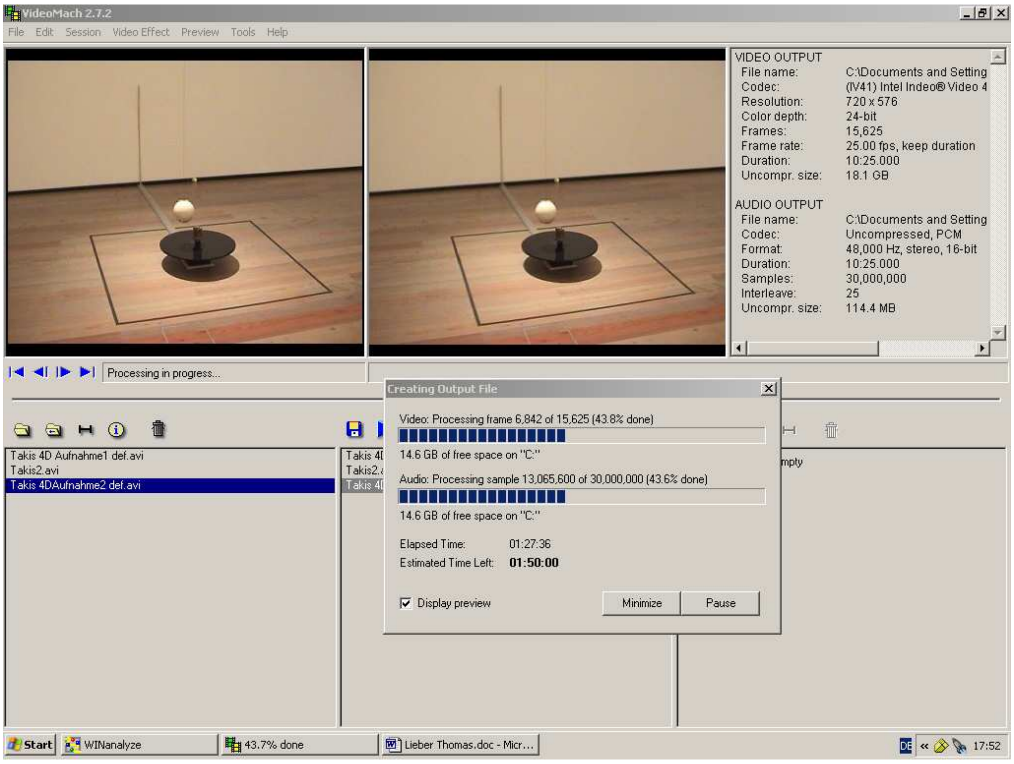

Fig. 3: Converting the encoding of a video sequence in VideoMach 2.7.2®

Analyzing the Sequences with WinAnalyze 3-D®, Version 1.9

Recording equipment for the following video sequences:

Digital Camera Recorder Sony DCR-TRV50E

Wide Conversion Lens VCL-HG0737X

Electret Condenser Zoom-Microphone ECM-HS1 is automatically synchronized with the camcorder's zoom.

Facts about the source video data:

- Resolution: 720 x 576 pixels
- Frame rate: 25 frames/second
- Data rate: 662 kBit/s

– Size of the video data: 24 bit
– Video compression: Intel Indeo®Video 4.5

In order to compare both video sequences, they have to be synchronized and calibrated using the software. Calibration takes place with the aid of the calibration model which goes for both views of the work if they run synchronically together. In a second step, the most important moving parts in the sequences are determined. Later, the movement of these points in the room is the result of the analysis. If both sequences are synchronized and calibrated, the software can perform a largely automatic analysis. The analysis calculates the points of the moved parts in the room over time.

Example 1: Tinguely, Jean

Basic Facts about the Work

– Title: *Lola T. 180—Mémorial pour Joakim B.* right acolyte. The work consists of a winged altar from a Bolliden Formula 1 car damaged in an accident and two small sculptures at its side, the so-called acolytes. In the following example, the right acolyte was analyzed.
– Date: 1986
– Dimensions: 350 x 500 x 180 cm
– Materials: cranium, corroded steel components, black textile veil, electric motor, aluminum plate
– Engine: 4 electric motors

Basic Facts about the Video Sequences

Duration: 0:56 min per sequence
Number of frames: 1,410 per sequence
Resolution: 720 x 576 pixels
Frame rate: 25 frames/second
Data rate: 662 kBit/s
Size of the Video data: 24 bit
Video compression: Intel Indeo®Video 4.5
Uncompressed file size: 1.6 GB

Brief Description of the Movement

– no frequent repeat
– regular

– Both cranial components rotate partly up and down, the spiral shaped steel component rotates completely
– The spiral scratches the aluminum plate with a scraping sound

Calibration:

Pasting of the calibration model into the video sequence and calculation of divergences.

Fig. 4: Attempting to calibrate the first video sequence. The edges of the stand serve as the calibration model.

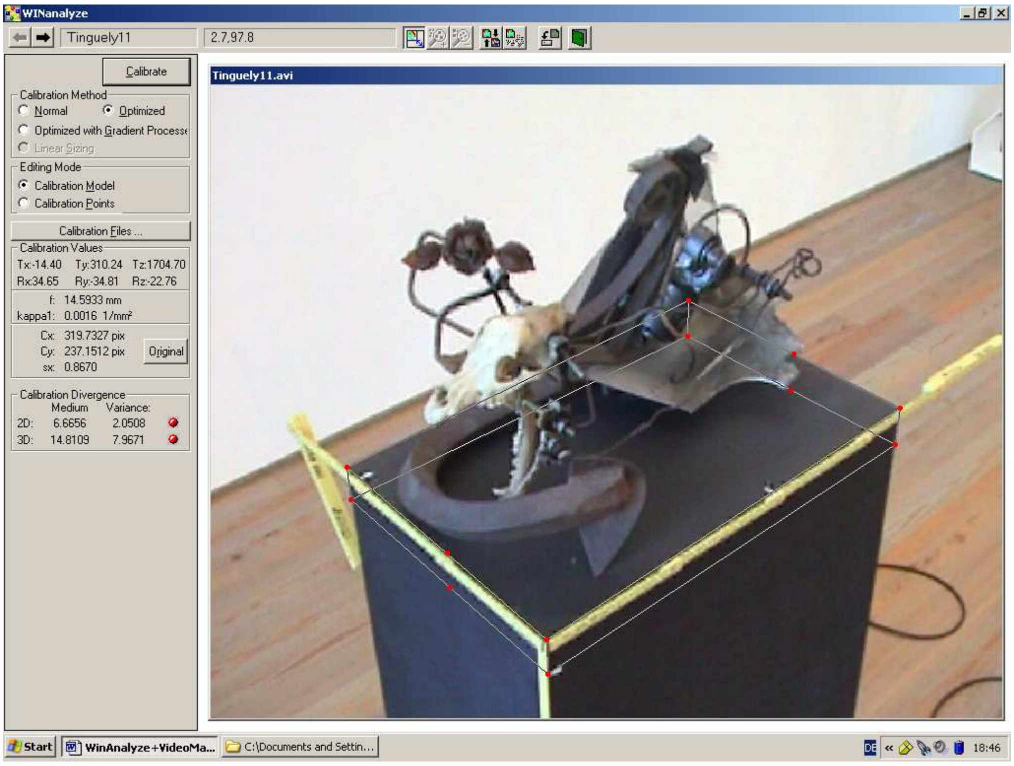

Fig. 5: Attempting to calibrate the second video sequence.

In this case, it is almost impossible to set the grid exactly in the second video sequence, because the far corner of the stand is not visible. This resulted in divergences between both calibrations of 178 mm! As a result, a second attempt at calibration was undertaken.

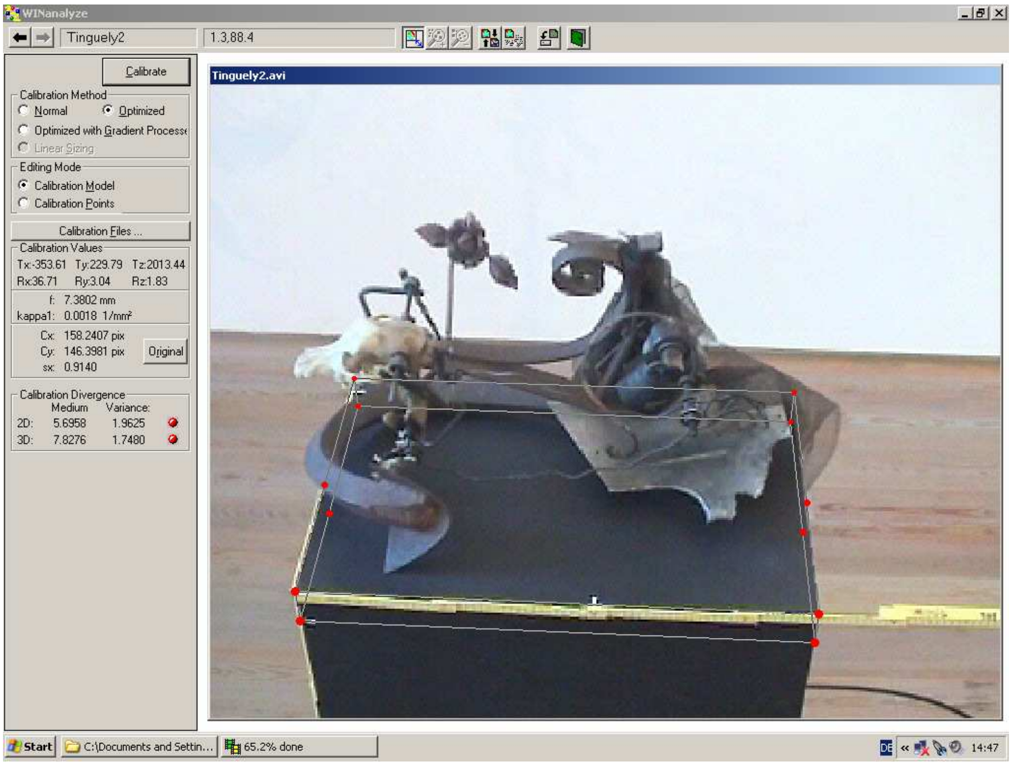

Fig. 6: Second attempt to calibrate the first video sequence.

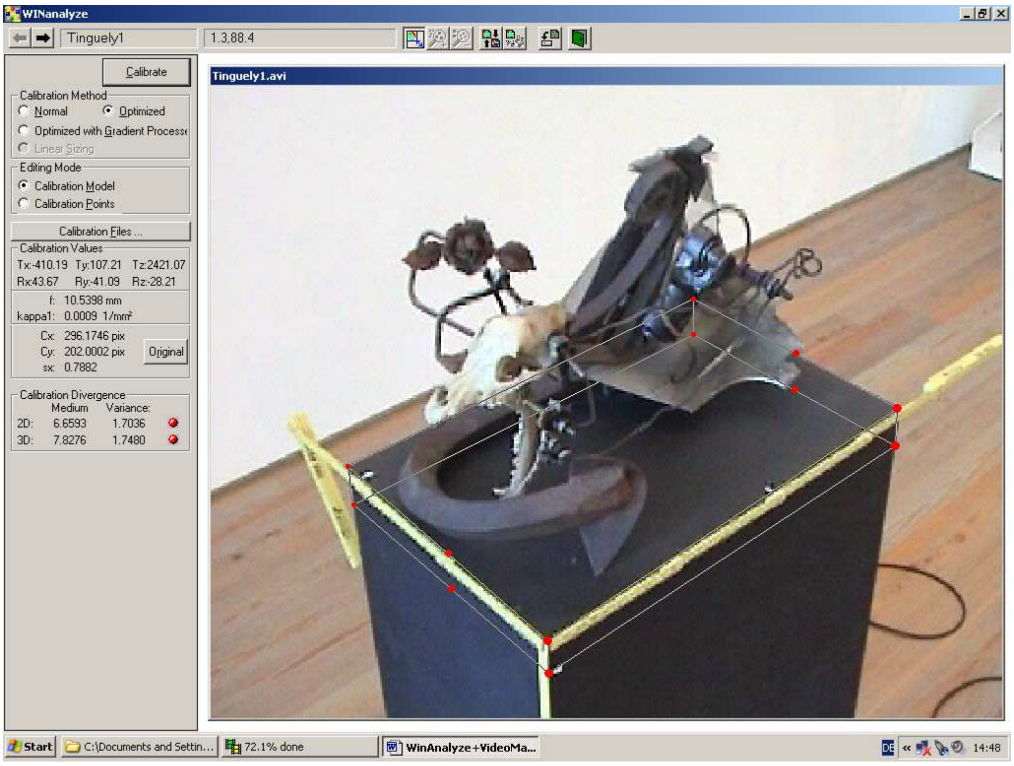

Fig. 7: Second attempt to calibrate the second video sequence.

After several tries, the difference between the two calibrations was reduced from 200 mm to circa 8 mm. This divergence falls within acceptable bounds.

Tracking

Tracking follows the set points whose movement is to be traced. Both video sequences can be played automatically or reproduced frame by frame. In so doing, the program can automatically recognize and trace the set points. Note: the set points recognize the object to be followed only poorly in the low-contrast frame. If this is the case, the points have to be, in part, carried from frame to frame with the mouse, and inaccuracies consequently result. The program also offers various possibilities for the increased contrast of the frame as an aid.

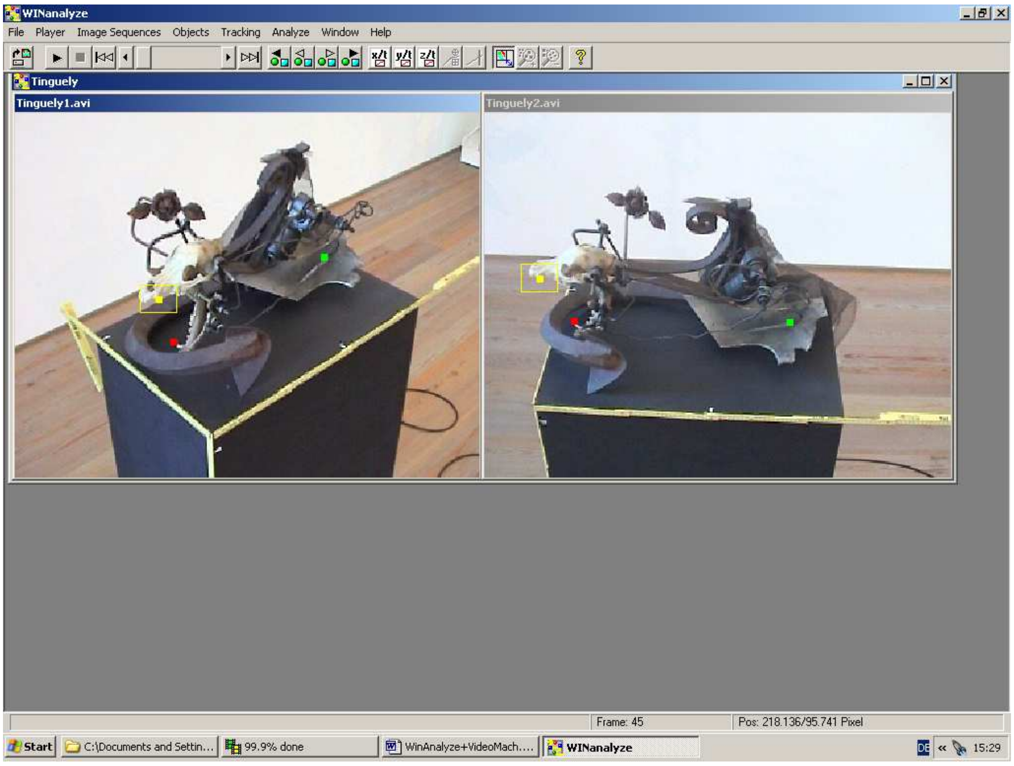

Fig. 8: Setting those points on the work whose movement is to be traced: upper jaw, lower jaw, and rotating steel component.

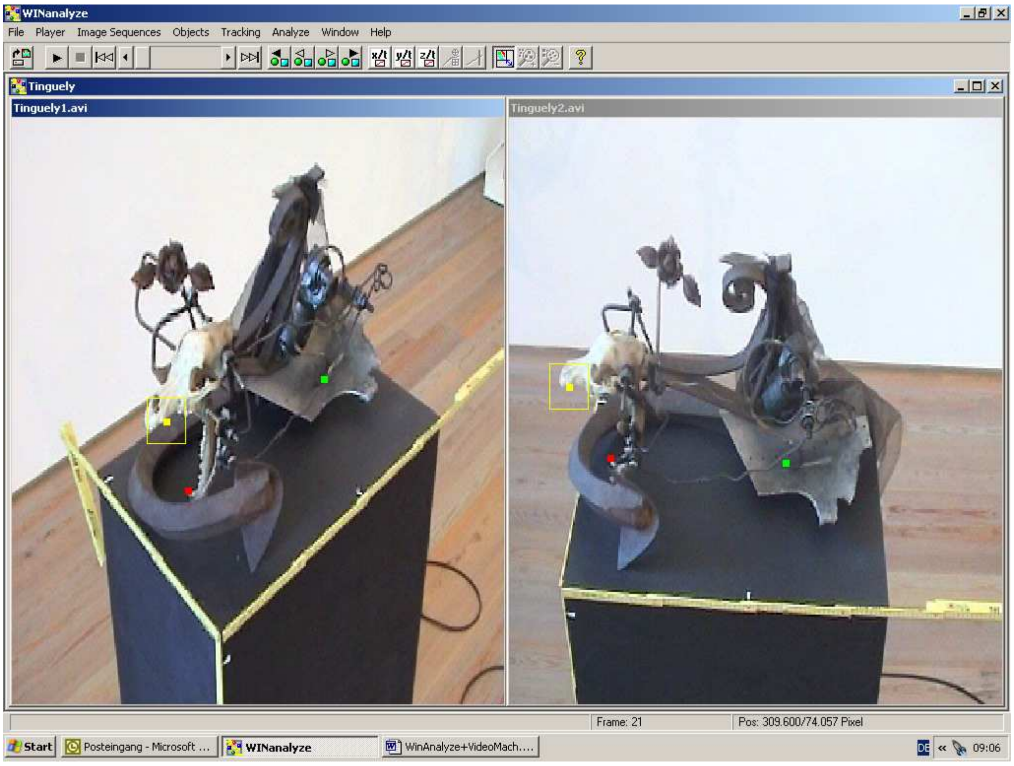

Fig. 9: Tracking the calibrated video sequences.

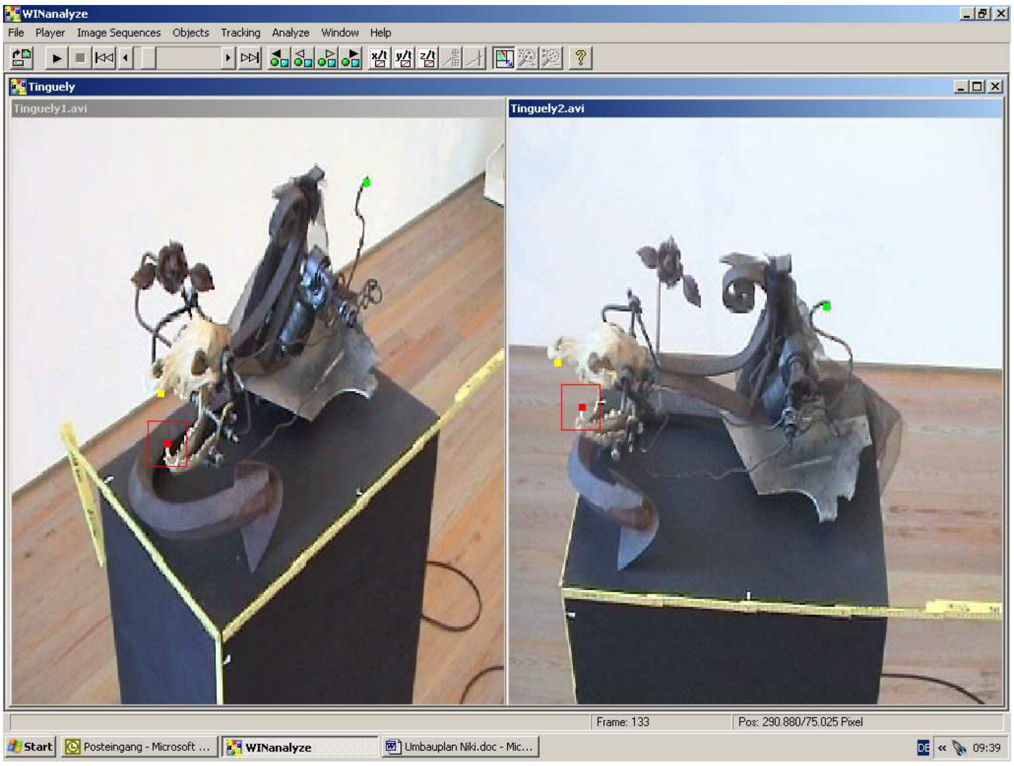

Fig. 10: Tracking the calibrated video sequences.

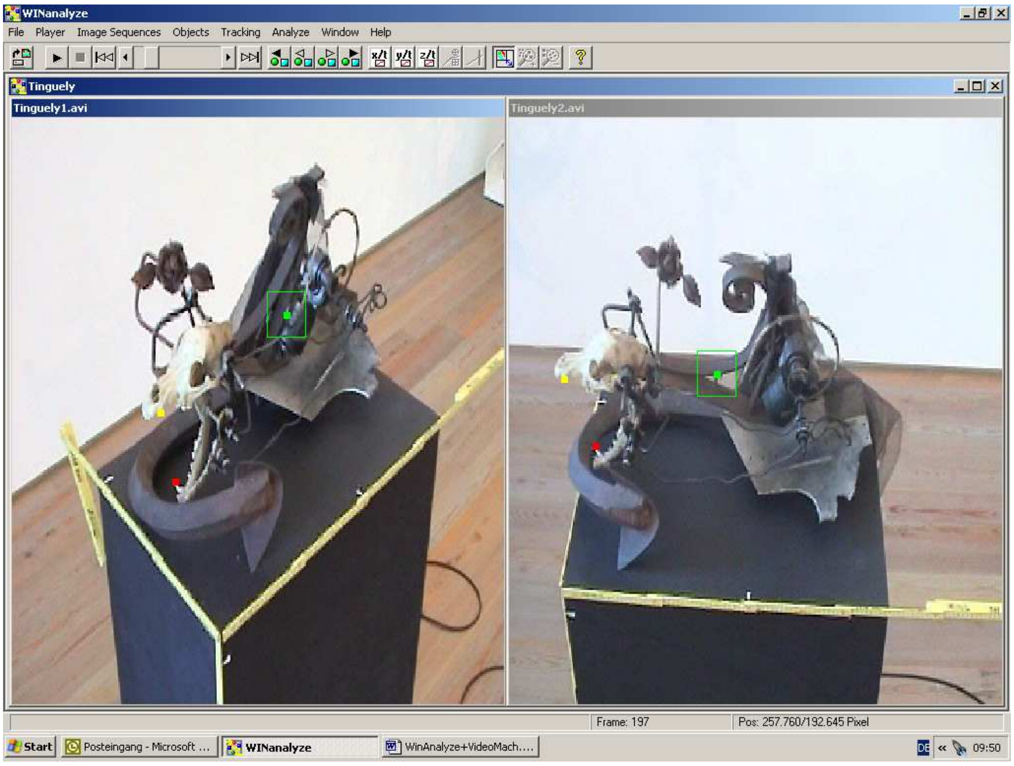

Fig. 11: Tracking the calibrated video sequences.

Analysis

The result of the analysis is shown in graphics directly on the monitor: x over t, y over t and z over t. All values can be exported via an output file in TXT format for further processing, e.g., in Excel.

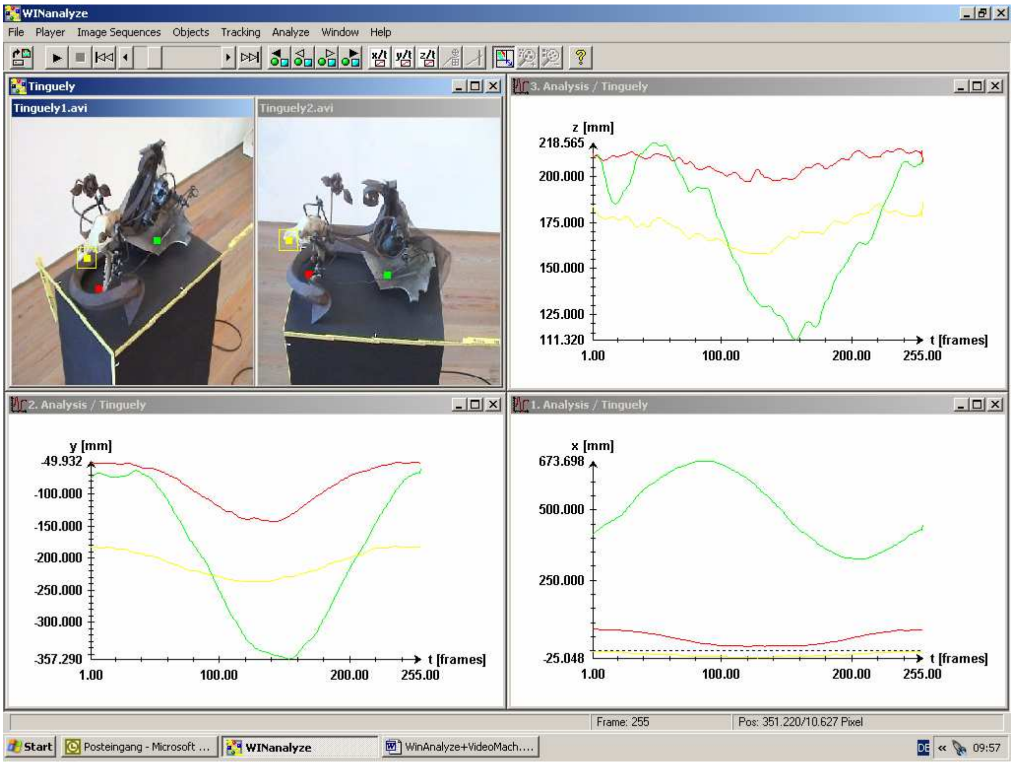

Fig. 12: Analyzed video sequence in graphs.

Evaluation

As the set points in the following case were not of a high enough contrast, tracking had to be performed almost exclusively by hand with the mouse frame by frame which, moreover, led to great inaccuracies in the analysis. This can be clearly seen in the curve of the z coordinate. The result can only be counted as an approximation of the actual movement.

Reasons for the error were, above all, the deficient contrast between the points and the background as well as the poor resolution of 720 x 576 pixels for this movement.

Possibilities for improvement:

– Special high-speed cameras produce a significantly better resolution and thus allow for more exact analyses.

– A clear marking of the points would have helped a lot.

Example 2: Csörgö, Attila

Basic Facts about the Work

- Title: *Untitled (1 tetrahedron + 1 cube + 1 octahedron =1 dodecahedron)*
- Date: 2000
- Dimensions: 180 x 110 x 80 cm
- Materials: metal frame, wood, strings, pulley, electric motor, weights
- Engine: electric motor, 220 V, 1 U/MIN
- Brief description: The work consists of a light, improvised appearing steel profile construction with an upper and lower segment. In the lower one are located the engine and mechanics, whilst in the upper segment are located 30 wooden dowels held on by thin threads of cotton wool, which form two geometric positions: One position forms a 12 sided polygonal body from the 30 wooden dowels, the other position simultaneously forms a dice, an equal sided pyramid as well as a double pyramid. Only 2 of the 30 dowels are fixed steadfastly; the remaining dowels have a free end with two threads of cotton wool and one end from which they hang fixed onto other dowels.

Basic facts about the video sequences

Duration: 2:57 min per sequence
Number of Frames: 4,429 per sequence
Resolution: 720 x 576 pixels
Frame rate: 25 frames/second
Data rate: 662 kBit/s
Size of the video file: 24 bit
Video compression: Intel Indeo®Video 4.5
Uncompressed file size: 4.3 GB

Brief description of the movement

- Repeated: the dowels run through both positions at a frequency of 1 minute.
- regular
- Back and forth movements of the forward movements of the dowels; circling movement of the mechanics of the engine of the counterweights hung from around the platform.

Calibration

Pasting of the calibration model into the video sequence and calculation of the divergences.

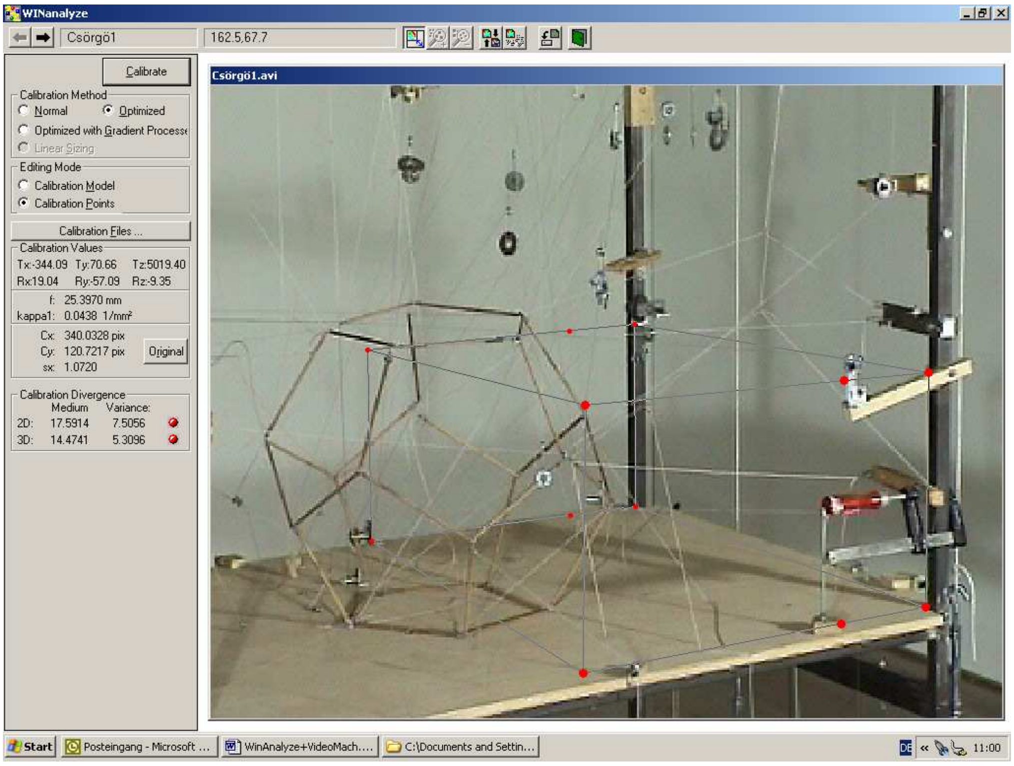

Fig. 13: Calibrating the first video sequence

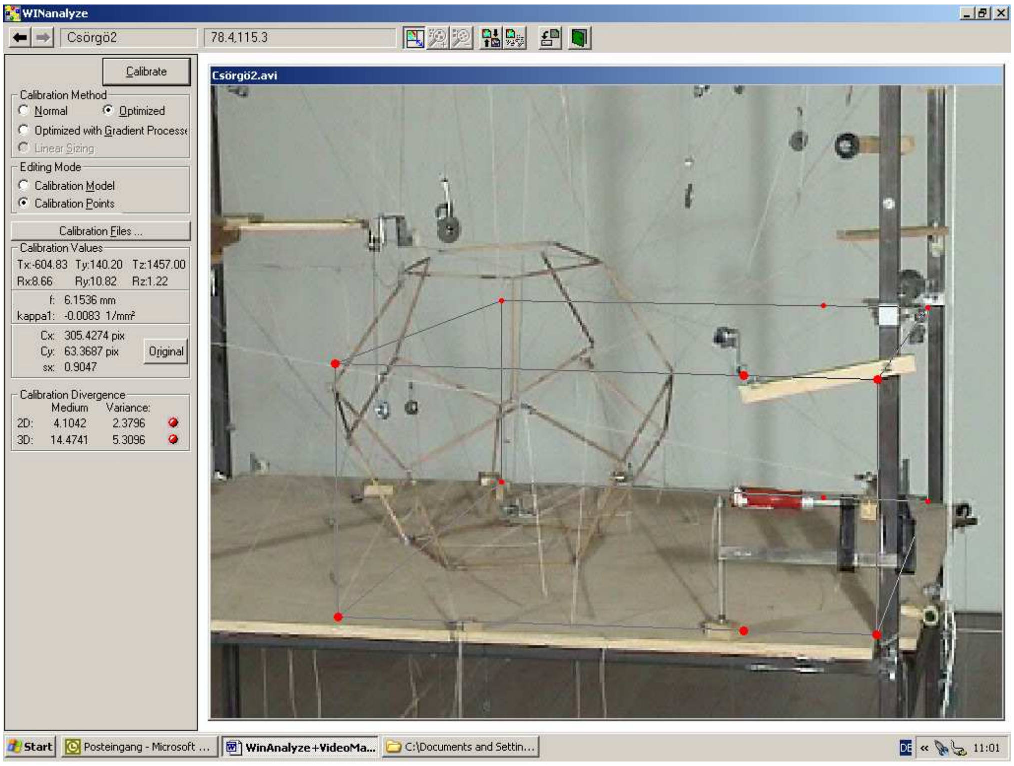

Fig. 14: Calibrating the second video sequence

The divergence between the calibration models is 5.3 mm which lies within acceptable bounds.

Tracking

34 points are to be analyzed. Every point set is an end point of one or several dowels. If two or more dowels are connected to one another, only one point is required for the tracking.

During tracking, it became very quickly apparent that the software could only very sketchily automatically track the points. For this reason, every point in every frame sequence had to be corrected by hand. The points were frequently covered by other dowels which resulted in gross inaccuracies. The resolution of the video sequences was also too low for the complex visual task. The tracking was ended after a while due to too high an effort and doubts over success.

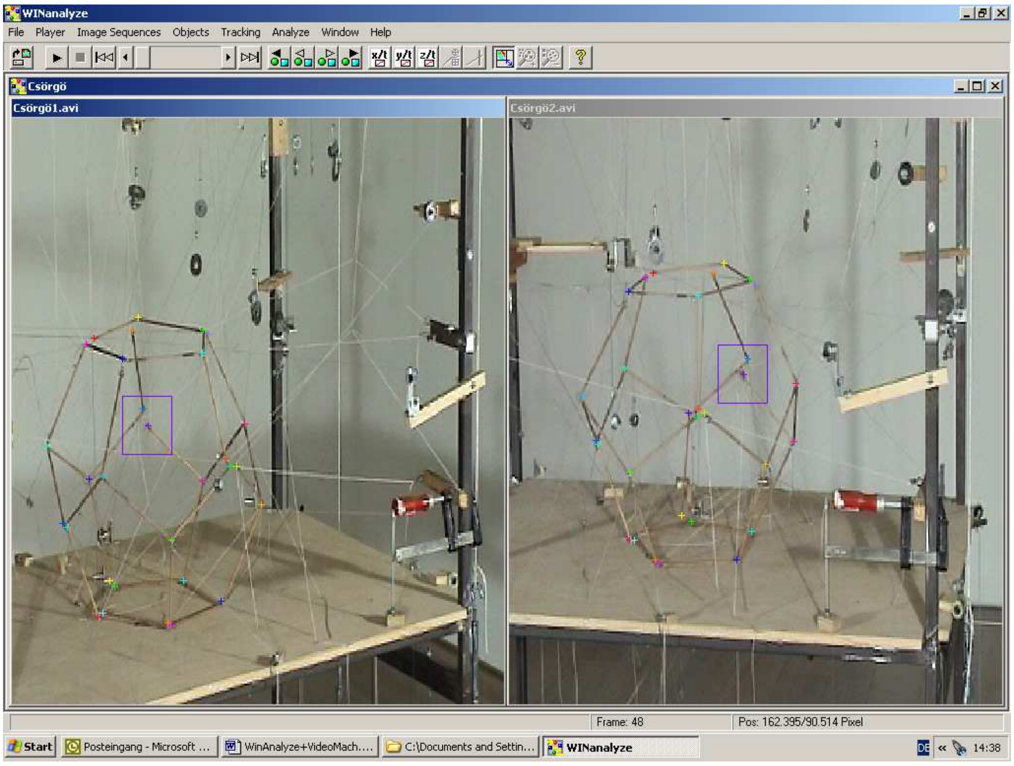

Fig. 15: Tracking the set points at the ends of the dowels.

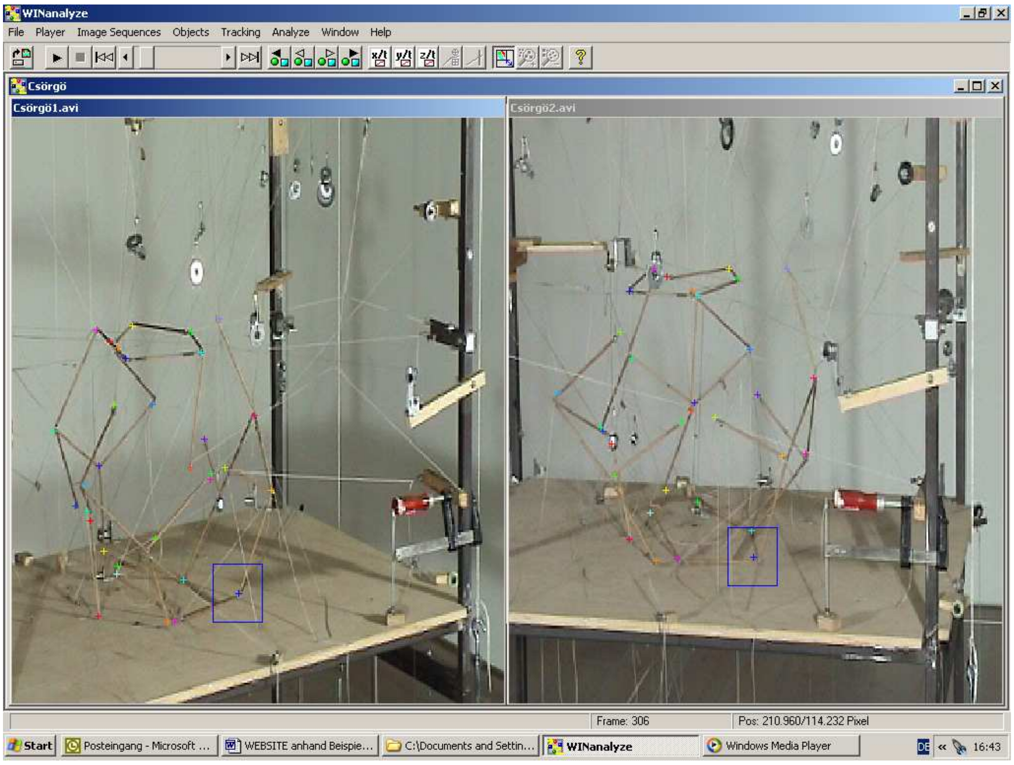

Fig. 16: Tracking the set points at the ends of the dowels.

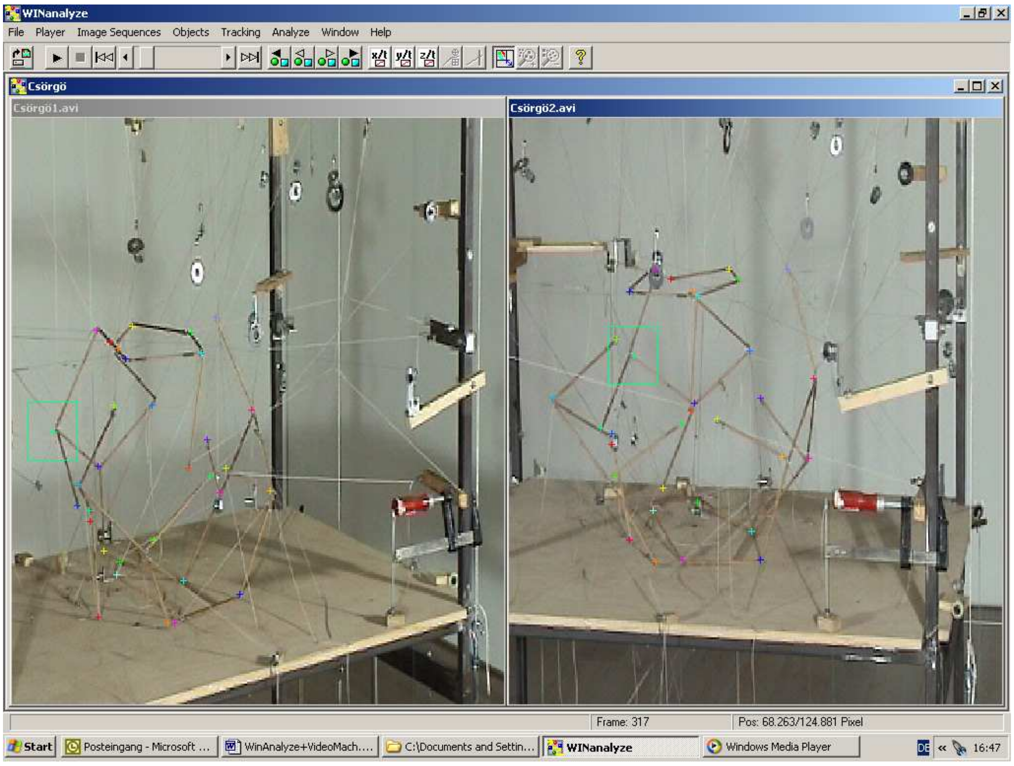

Fig. 17: Tracking the set points at the ends of the dowels.

Analysis

The analysis of the prematurely aborted tracking provided an unclear graphic result. An evaluation would, however, be possible, because each individual point has a protocol of the space coordination over time.

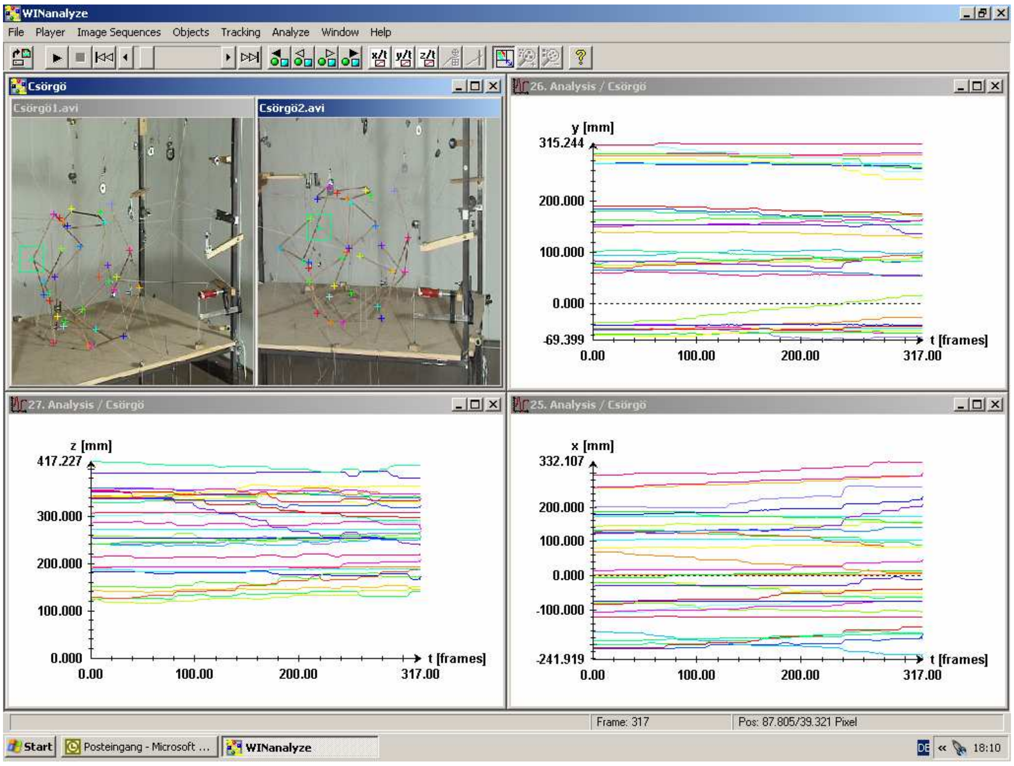

Fig. 18: Analyzed video sequence as graphs.

Evaluation

The software could not automatically follow the thirty-four points, because they overlap each other too often. For this reason, the tracking had to be carried out almost entirely with the mouse frame by frame which again led to large inaccuracies in the analysis. The resolution of 720 x 576 pixels, very low for this movement, made an accurate analysis impossible.

Possibilities for improvement:

- The contracting of a specialized outside firm would be sensible for such a complex application.
- Special high-speed cameras produce a significantly better resolution and thus provide more accurate results.
- A clear marking of the points would have helped a lot; this was, however, impossible due to the movement of the dowels in a small space.

Example 3: Takis, Panagiotto Vassilakis

Basic Facts about the Work

- Title: *Électromagnétique*
- Date: 1959
- Dimensions: diameter of the sphere 16 cm; diameter of the acrylic disk 55 cm;
- Materials: wooden sphere with 8 embedded iron pins, acrylic glass plate with stand, electromagnet;
- Brief description: the sphere hanging from one cord over an electromagnet is attracted by it in regular time intervals and then immediately released again. In that way, the sphere swings over the electromagnet in a regular and seemingly coincidental movement as if directed by a magic hand.

Basic Facts about the Video Sequences

Duration: 3:26 min per sequence

Number of frames: 5,155 per sequence

Resolution: 720 x 576 pixels

Frequency of frames: 25 frames/second

Data rate: 662 kBit/s

Size of the video file: 24 bit

Video compression: Intel Indeo®Video 4.5

Size of the uncompressed file: 6 GB

Short Description of the Movement

- Nonrepetitive
- The ball moves in the space around the electromagnet at a certain tolerance.
- The frequency is set by the electromagnet.
- The movement greatly depends on the distance between sphere and electromagnet and on the type of suspension of the sphere.

Calibration

Pasting of the calibration model into the video sequence and calculation of the divergences.

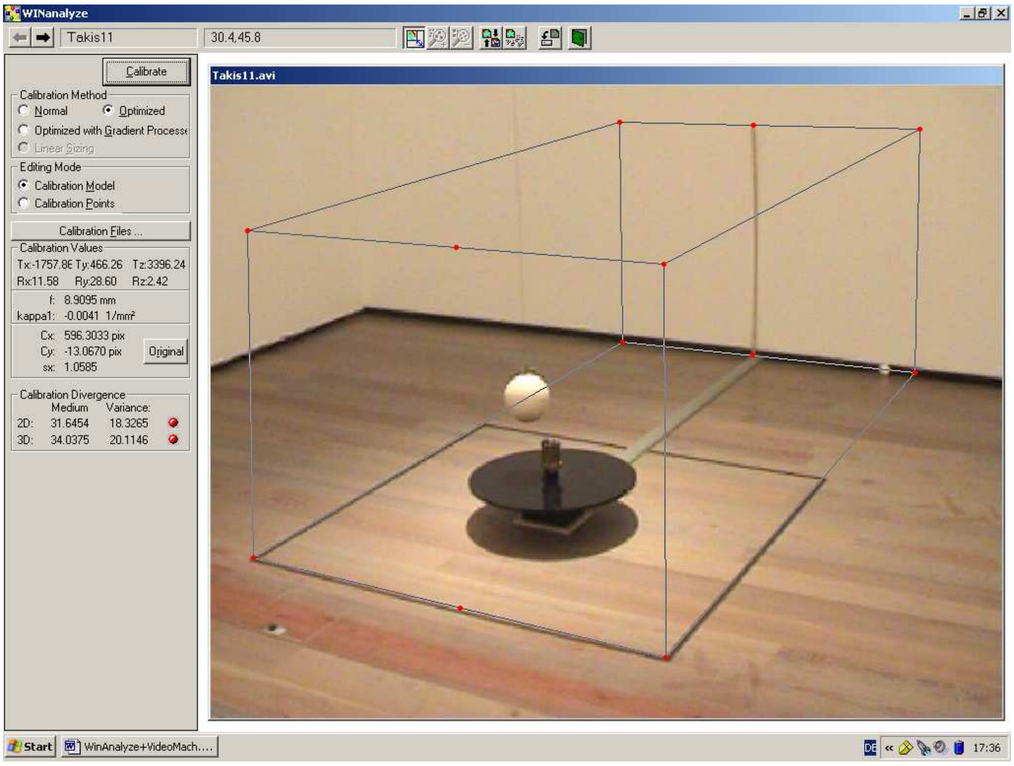

Fig. 19: Calibrating the first video sequence: the cube around the work as well as the tape measure on the wall serve as a calibration model.

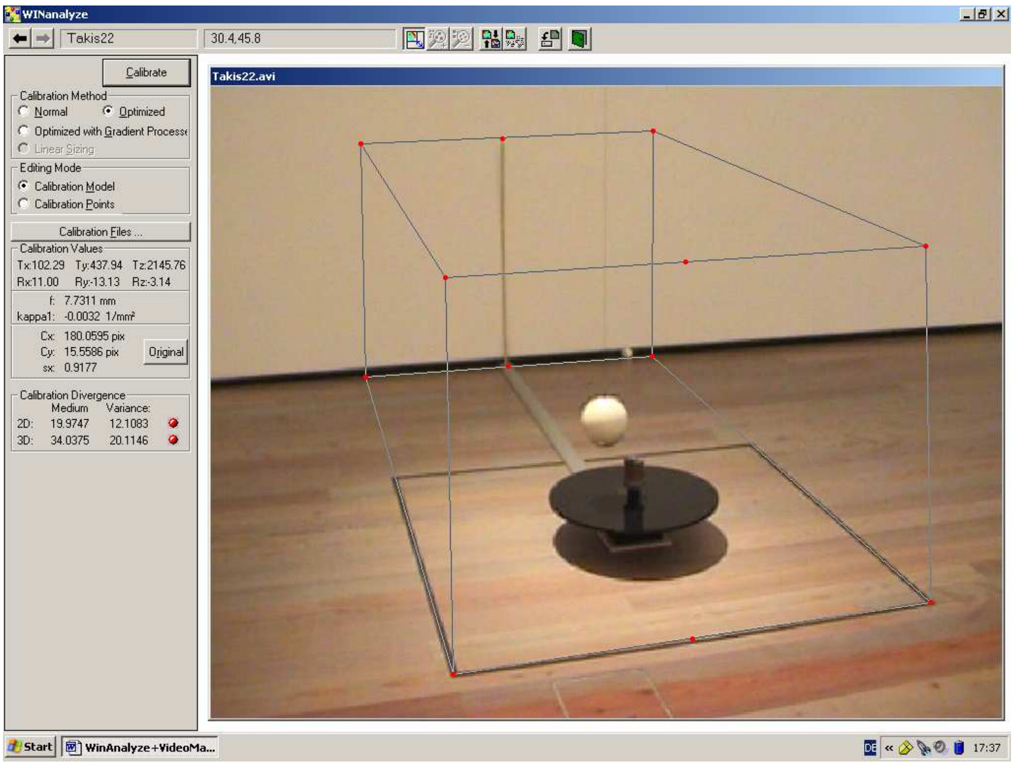

Fig. 20: Calibrating the second video sequence

Tracking

An object is analyzed. This object is the point at which the sphere meets the cord, that is, the upper vertex of the sphere.

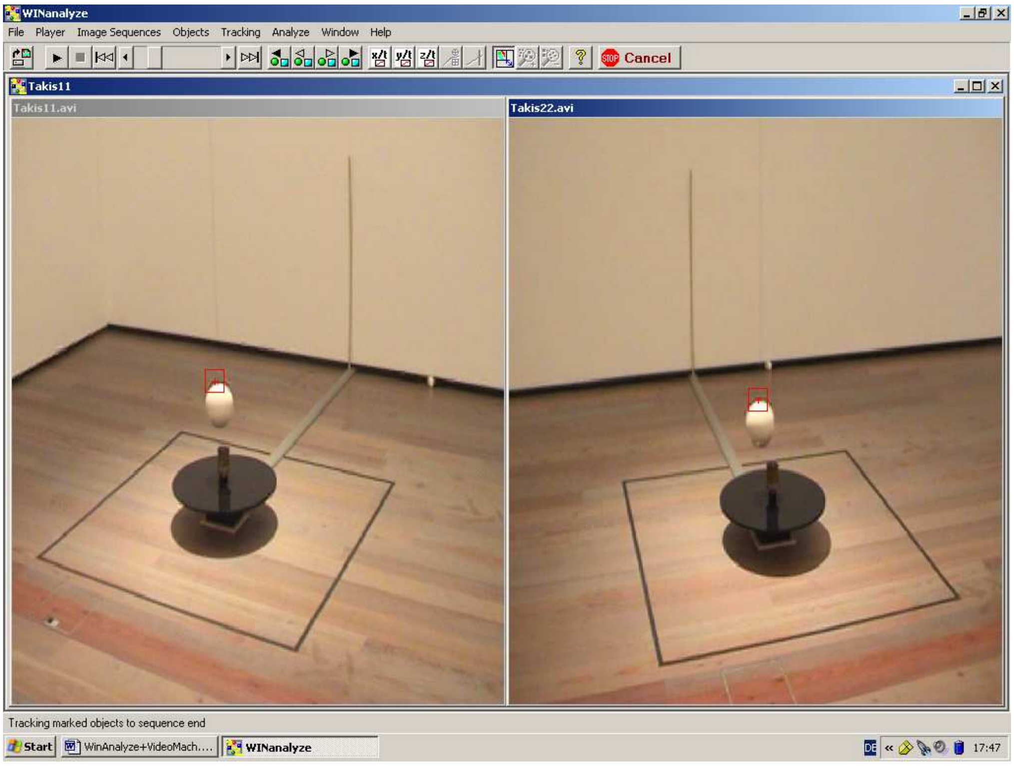

Fig. 21: Tracking the set point on the vertex of the sphere.

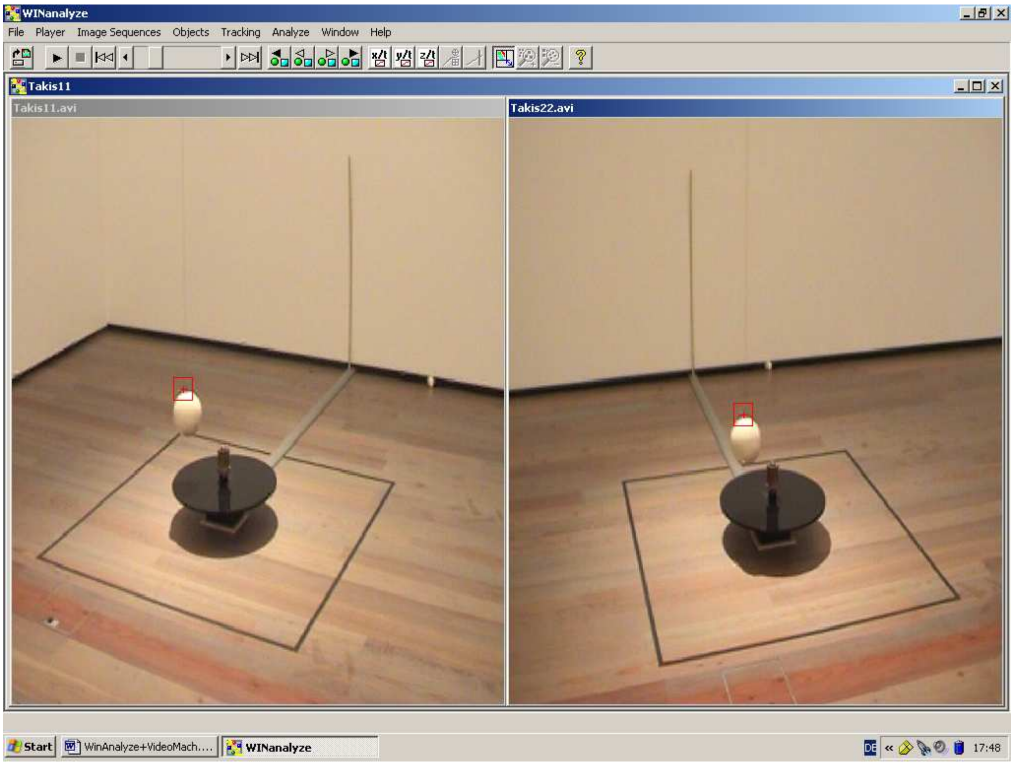

Fig. 22: Tracking of the set point on the vertex of the sphere.

Analysis

The result of the analysis is shown in graphs directly on the monitor: x over t, y over t and z over t. All values can be exported using an output file in TXT format for further processing, e.g., in Excel.

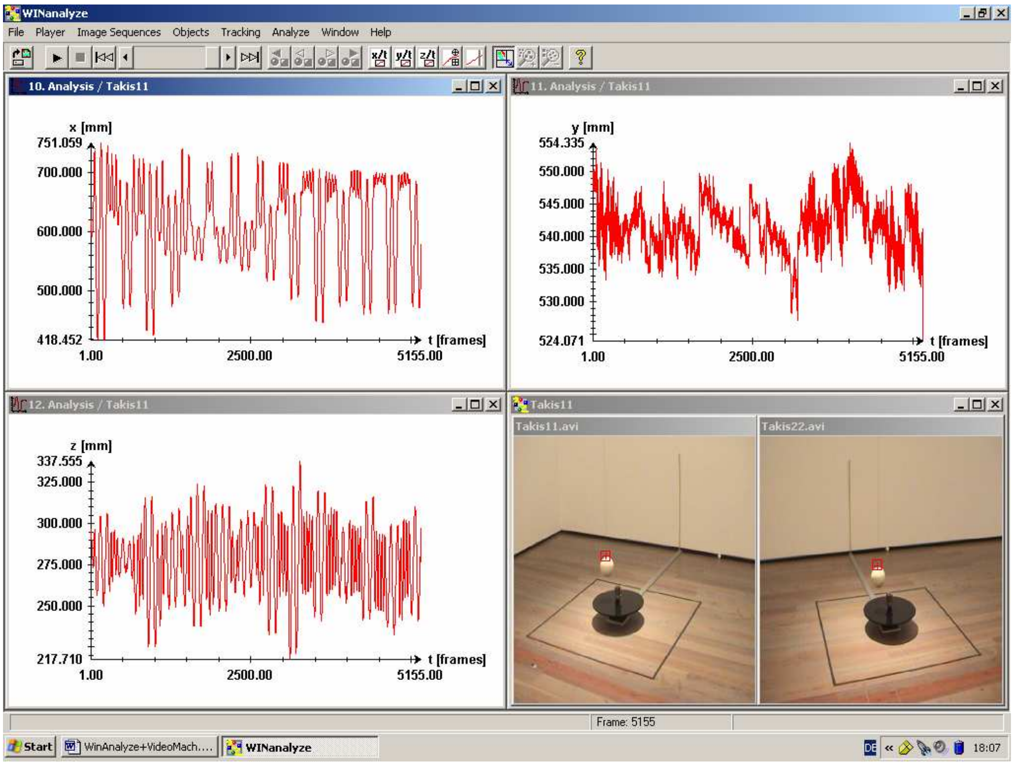

Fig. 23: Analyzed video sequence in graphs.

Evaluation

The software was able to follow the point to be analyzed on the vertex well. For this reason, the tracking could succeed using the software exclusively, and thus the analysis becomes much simplified and accurate. The resolution of 720 x 576 pixels was sufficient for this analysis. The analysis ran very smoothly and successfully.

Possibilities for improvement:

– A marker on the vertex of the sphere would permit more accurate results. The algorithm of the program functions using the brightness of the point to be followed. Here the brightest point also moves on the surface somewhat, because the light source is fixed and the sphere moves. That is the case with many objects, and can be compensated using a color different to that of the marker.

– Special high-speed cameras produce a significantly better resolution and thus provide more accurate results.

Summary

3-D video analysis represents the only possibility for objective documentation of movement in space over time. The result, the analysis, is largely independent of the physically existing artwork. Therefore, more than just applicability and uses should be considered when deciding for such a time and finance consuming documentation. If, however, both are available, such an analysis is also realizable for laypersons working by themselves and thus saves costs.